ON EVALUATION OF EMF RISKS AT A MULTISITE BROADCAST FACILITY USING THE UNCERTAINTY OF MEASUREMENT PERSPECTIVE

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Abstract - **This work deal with the EFM characterization of a complex multi-site broadcast facility. This facility is a good representative of the complex clustered broadcast sites found in Brazil. Usually the measurements of EMF done in broadcast facilities tend to underestimate the importance of the correct evaluation of the uncertainty of measurement. This fact can lead to incorrect conclusions and expose the workers and general population to undesirable levels of EMF.**
Keywords **– Electromagnetic field, field strength measurement, uncertainty calculus, electromagnetic fields health, electromagnetic fields safety, electromagnetic fields effects.**

I. Introduction

In despite of the current legislations about the electromagnetic fields (EMF) control in telecommunications facilities, a large number of broadcast facilities don't have an appropriate measurement of the electromagnetic fields presents in their facilities. This is particularly true for Brazil. Only in 2003 this country adopts a mandatory regulation to limit the EMF at telecommunications facilities [1]. This regulation is heavily based in ICNIRP regulations but it give only a general references in the methodology of EMF measurement and no word about the uncertainties associated to the measurements.

This regulation states that the fields can be evaluated in two forms, using theoretical calculations, or, measuring the site, in both cases this analysis must be due by a professional electrical engineer.

In Brazil the theoretical calculations have problems due to imprecision of the available data. In 2004 and 2005 the EMF was theoretically calculated using the method exposed in [1] and found that in a multi-site environment the errors in theoretical calculations, can be more than two orders of magnitude relative to measured fields. These calculations are done for the environment of the *Centro de Comunicação Lumen* (CCL) a broadcast communications facility located in Curitiba, Brazil.

II. Description of study environment

CCL site have 2 FM analog radio stations and 3 UHF TV stations on his supervising.

The neighborhood of CCL is composed of 16 broadcast stations clustered in a 1000 m x 850 m. These stations are composed by FM analog radio and PAL-M analog TV systems. Curitiba city have a total of 33 FM and TV stations. The stations involved in this cluster have a large variation in installed power and mostly of them have old vacuum tubes transmitters. Figure 1 show the cluster of broadcast stations. Some points in fig.1 (representing towers) have two or three radiating sets. This cluster is locater in Pilarzinho neighborhood in Curitiba, Brazil.

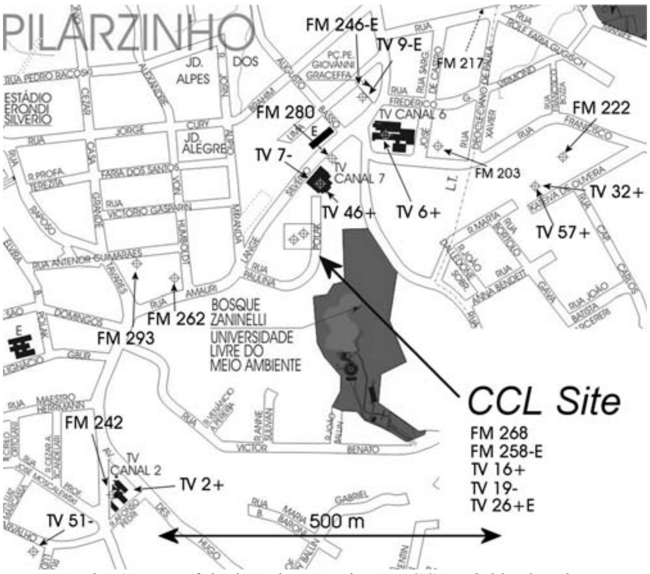

Fig. 1. Map of the broadcast stations at CCL neighborhood

The draft of CCL site is show in fig. 2. This site shared RF transmitters, an administration building, two houses (one inhabited), and a museum. The points of measurements are showed too.

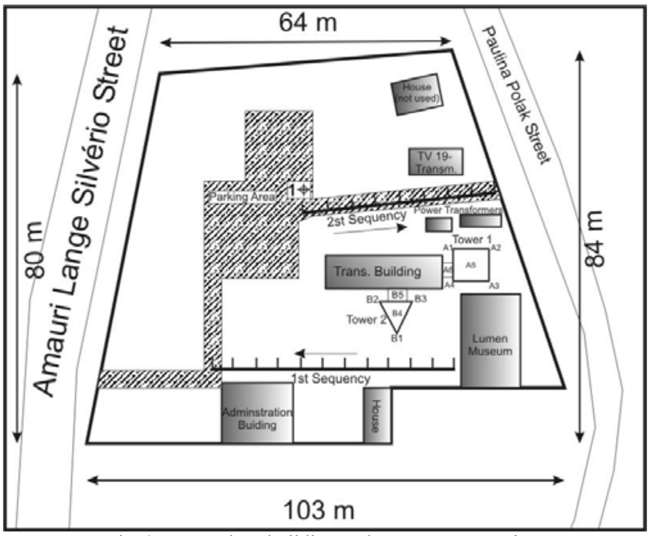

Fig. 2. Transmitter building and measurement points

Internal divisions of the Transmitting Building are showed in the fig. 4.

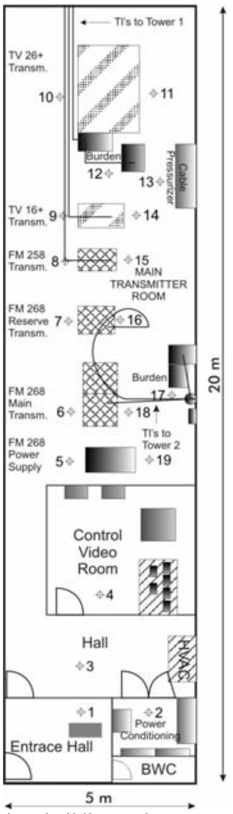

Fig. 3. Transmitter building and measurement points

To assure that the fields are evaluated correctly all stations of FM and TV in Curitiba has their data analyzed, this included, the transmitters output powers, effective irradiated power (EIRP), altitudes and tower weights, antenna types, number of bays, and geographic localization. These data are provided by Anatel and by field surveying for more precise analysis of the stations.

The fig. 4 show the histogram of the effective isotropic radiated power of all stations of Curitiba and table I show the output power at the transmitters in CCL Site, this information is important to evaluate the leakage of radiation at the transmitter's room.

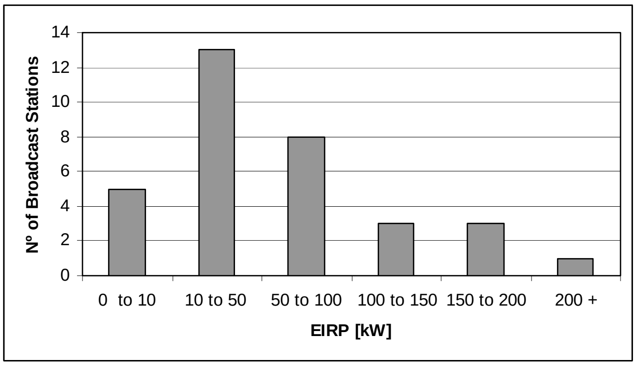

Fig. 4. Histogram of EIRP in FM and TV broadcast stations in Curitiba

TABLE I
OUTPUT POWER OF TRANSMITTERS AT CCL SITE

Station	*Output Power (kW)*	*EIR Power (kW)*
FM 258	4	5,4
FM 268	35	148
TV 16+	5	34
TV 19-	10	27
TV 26-	1.7	2.3

III. Methodology of Measurements

The CCL site was divided in two areas, an intern to transmitting building and an external area outside the buildings.

These two areas have different characteristics. Internal area has a predominance of near electromagnetic fields. The external areas have only radiating near and far fields, and have significant contributions of the field radiated from the neighbor stations.

In the evaluation of the internal EMF used the punctual sampling. The principal reason for this metric is the fact that this room is used only eventually. The points are selected in front the control panels and in the back of the transmitters at the access ports. The height of measurement selected was 1.5 m, this height combine two important factors. The fist is the mean height of the thorax of a person and the second is that the RF output stages of the transmitters are located at this height. A spatial measurement conducted showed that this height has the highest values of electric fields in the transmitter room of CCL.

The evaluation of external areas used a mix of punctual measurement in sensitive points and line evaluations of the fields following the principal areas of people permanence. All electrical field measurements were done in 2 m height evaluating the international practice.

In all cases the fields are measured using a broadband field meter Wandell Gottermann EMC-20 with a Narda Type 8 probe. This equipment has bi-annual calibration in Narda and the last calibration was 5 months before the measurements. A spectrum analyzer was used for an evaluation of the multi station contribution of total EMF. A good guide to sampling strategy can be found in [2].

The methodology follows the good practices established in, [3], [4], [5], [6] and [7]. In [5] its possible find information to deal with deferent types of modulation and [7] show some parameters for guidance in uncertainty calculus.

The consideration of uncertainty in evaluation of EMF is necessary to assure scientific significance in the measurements and to provide measurements that can be compared. This work used the methodology of [8], in [7] the uncertainty components showed are not sufficient to express the correct uncertainty in a commercial meter used in this work. Some more common components like temperature and resolution and others more particular like ellipse ratio and television signals picture content are not stated in this publication.

In despite of this was necessary a more detailed budget of the uncertainties before the establishment of the dominant components of uncertainty. Tab. II shows the principal uncer-

tainty sources used and the divisor of their respective probability distribution.

TABLE II
UNCERTAINTY BUDGET FOR BROADBAND METER

Component	*Type of Uncert.*	*Divisor*	*Source*
Std. Dev.	A	√n	measurement
Linearity	B	√3	manual
Isotropy	B	√3	manual
Ellipse ratio	B	2	calib. certificate
Freq. Response	B	2	cabib. certificate
Temperature	B	√3	manual
Resolution	B	√12	manual

Possible sources of errors in evaluation of the meter specifications are the use of declared uncertainty components of the instrument without translating them in the standard uncertainties and account them completely. Ref. [6] state that a isotropic probe should have a mean deviation less than 1 dB, but Narda probe combined with a data logger have a deviation of ± 1 dB and some manufactures more, but after you combine al uncertainties you can have a total uncertainty less than ± 3 dB that complies the ITU R-SM 378-6 [9].

IV. Result of Measurements

Two series of measurements are done in CCL site in 01/31/2006 and 08/04/2006. In this work are showed some most significative measurements of the CCL Site.

Internal measurements showed all points with fields lower than general IEEE/ANSI 27 V/m (for 30 to 400 MHz limit). This is a good surprise in the internal area because the high levels of output power in transmitter operation. The two internal points with regular permanence of workers showed fields lower than 5 V/m. In the video control room (point 4 in Fig.4) the electric field was 1.6 ± 0.21 V/m, this is a shielded room, and 4.76 ± 0.59 V/m for the entrance hall of transmitters building. The highest internal field was 18.02 ± 2.23 V/m (point 11) in the main transmitter room. The points and the values of strength field are showed in fig. 4, the location of the points are showed in fig. 3.

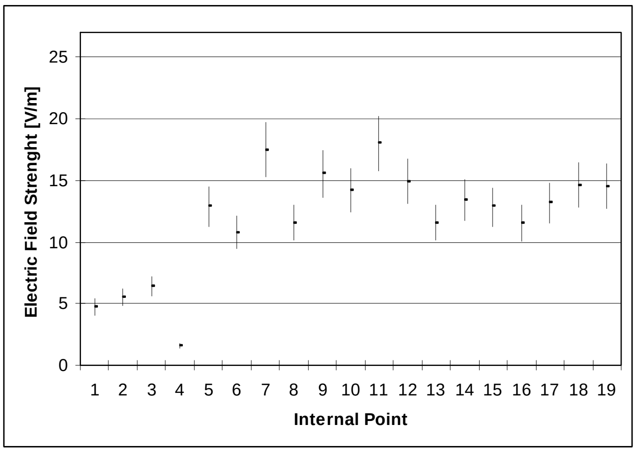

Fig. 4. Electric field strength in the transmitting building

In external areas field exceeding the 27 V/m general limits are found. The maximum value is 46.17 ± 5.74 V/m in the stairs of FM 268 tower, point B4 in fig. 2.

The external measurement points with levels higher than general limiting levels no extrapolated the occupational limits of IEEE/ICNIRP. The measurements performed show that the linearity deviation and isotropy are dominant in the uncertainty calculus. The standard deviation was little influence and the resolution has no significant influence. For the CCL Site this work not found significant long term drift in the points measured with 7 months apart. The natures of broadcast 24 h continuous emissions have influence in the low standard deviation found. In fig. 5 and fig. 6 the measurement sequences 1 and 2 are showed.

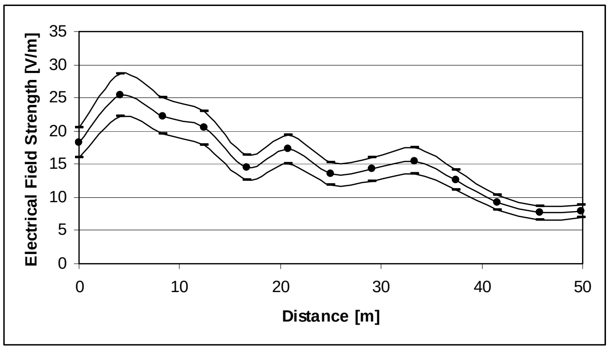

Fig. 5. Electric field strength in the 1st sequence, external area.

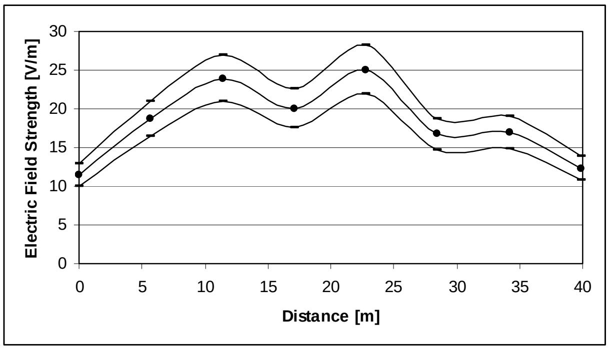

Fig. 6. Electric field strength in the 2nd sequence, external area.

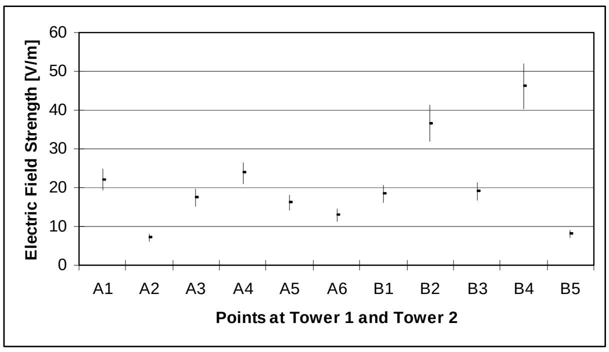

Fig. 7. Electric field strength tower 1 (A) and tower 2 (B).

An important result in the measurements performed in CCL Site is the little standard deviation in relation of the

final expanded uncertainty, the worst standard deviation in all measurements was ±0.34 V/m in contrast with ±1.46 V/m of expanded uncertainty, point 19 in fig. 3. Another interesting found is the comparison of the maximum field and mean field provided by EMC-20 and the expanded uncertainty. In the highest strength field was the mean of 46.14 V/m with a maximum field of 49.32 V/m against 46.14 ± 5.74 V/m (max. 51.88 V/m with 95% of confidence level consideration) using expanded uncertainty. This shows the risks of underestimating the importance of a detailed uncertainty calculus in this kind of health sensitive study.

A curious found was the similar standard deviation in one minute measurement and the standard deviation in 6 minute measurement. A more detailed work will be done to evaluate if this kind of stations have little short term drift and can originate a little time measurement in this particular telecommunication stations or if is a coincidence.

To account the contribution of neighbor stations was performed using two sets of broadband antennas with a spectrum analyzers, these equipments can't be used to measure the absolute field strength by a wrong chose of a cable and an antenna without the proper calibration to field strength measurement. However it can be used to evaluate the relative contributions of the stations in a point near the center of CCL Site. The two sets are composed by an Agilent E7402A ECM receiver with a Rohde & Schwarz HK 116 Bi-conical antenna and a HP 8558B spectrum analyzer with a Diamond D-130J Discone antenna. The measurement and calculation of relative fields follow [3], [4], and [5] recommendations.

The relative contributions for the total Electric Strength Field for the CCL stations are 30.3 % for HP8558 measurements and 26.8 % for Agilent E7402A measurements of the total electric field strengths, the point of measurement is showed in fig. 3 point 1. Results of these two measurements are similar considering the possible uncertainties involved. The uncertainty of relative measurements using the spectrum analyzer are accounted only by general values found in [10] and [11] due to lack of calibration of some components. Typical uncertainty of this kind of measurement can rise to ± 5 dB of expanded uncertainty considering only Type B estimations. This exceeds the uncertainty values recommended in [9]. To reduce the uncertainties to an appropriate level is necessary experienced people with metrological background performing the measurements and appropriate calibration of the antenna, cable, spectrum analyzer set.

IV. Conclusion

The account of uncertainties in the measurement is a very important step in the evaluation of EMF present in telecommunication stations. The broadcast stations show the highest powers in all telecommunication stations and the FM service have the most extreme limits of EMF. Considering only single measurements or standard deviation or mean value with highest value the measurements will be underestimated because the nature of uncertainties present in strength field measurement.

In the CCL site no measurements exciding the limits relating them with IEEE/ICNIRP levels. Because the safety margin adopted by ICNIRP and IEEE, none bioeffects are expected in the occupational and general permanence zones. A useful report of possible threshold levels of EMF that can originate bioeffects is found in [11]. This measurement results are valid in CCL site study and the results can't be used in another broadcast station in a strict form. Another stations of this kind must be evaluated case by case. The form of evaluation considering the uncertainty components in a full account is strongly recommended.

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